Validity of Observational Job Analysis Methods

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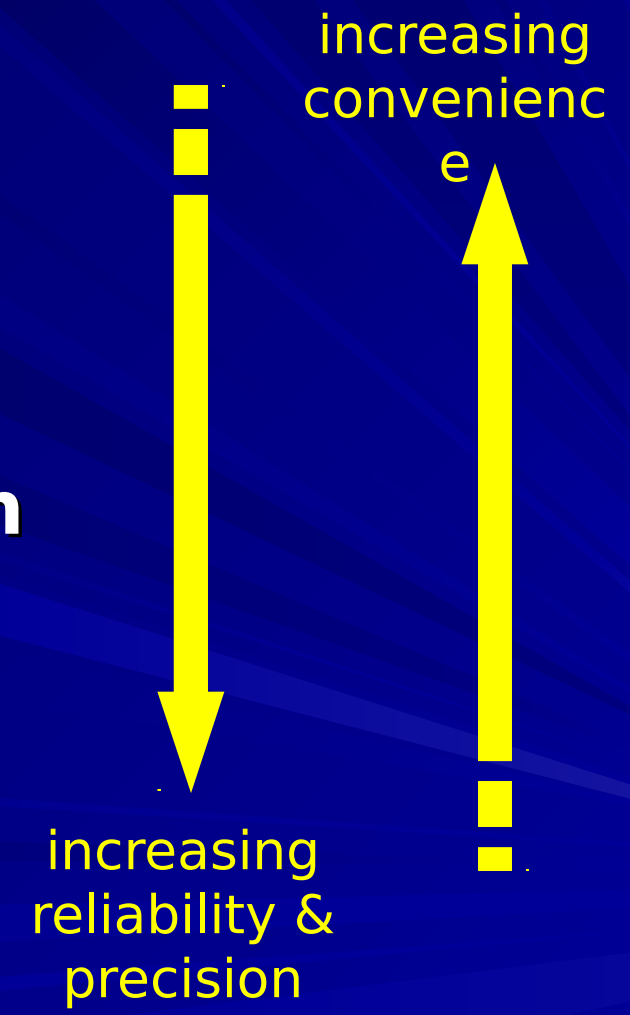
presentation outline

- Physical risk factors for WMSDs and job analysis methods for their characterization
- NIOSH study of observational job analysis methods
  - Methods
  - Results
  - Conclusions
- Validity considerations in job analysis

methods for assessing WMSD risk factors

- Job Titles/SIC code
- Worker Self Report
- **Systematic Observation**
- Direct Measurement (Instrumentation)



goals for exposure characterization
(Kilbom, 1994)

- *External Validity* - identify exposures associated with increased risk for WMSDs

✓ **epidemiology**

★ *Internal Validity* - exposure is classified accurately relative to a known standard

✓ **biomechanics**

Objective

- Group methods of scaling risk factors used in observational-based job analyses
- Compare observational estimates of risk factors with instrumentation-based measures
  - electrogoniometer – wrist/forearm posture/kinematics
  - optical motion capture – shoulder posture/kinematics
  - electromyography – force of exertion
- explore the likelihood and nature of errors in exposure characterization

jobs simulated in the laboratory

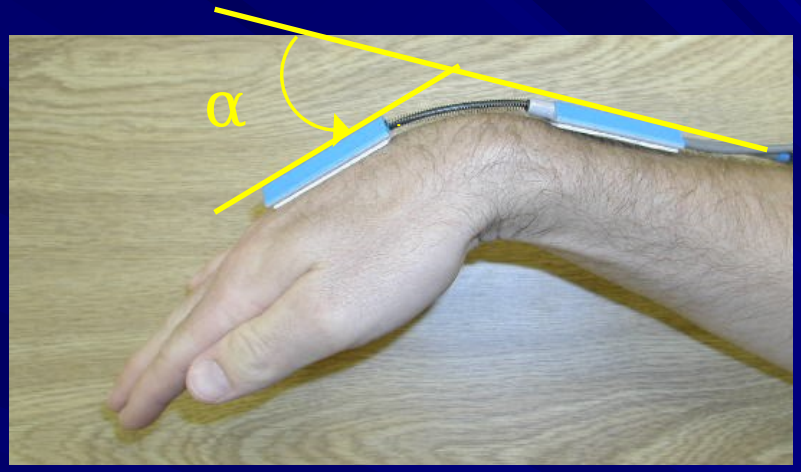
Job A
~ 13 s

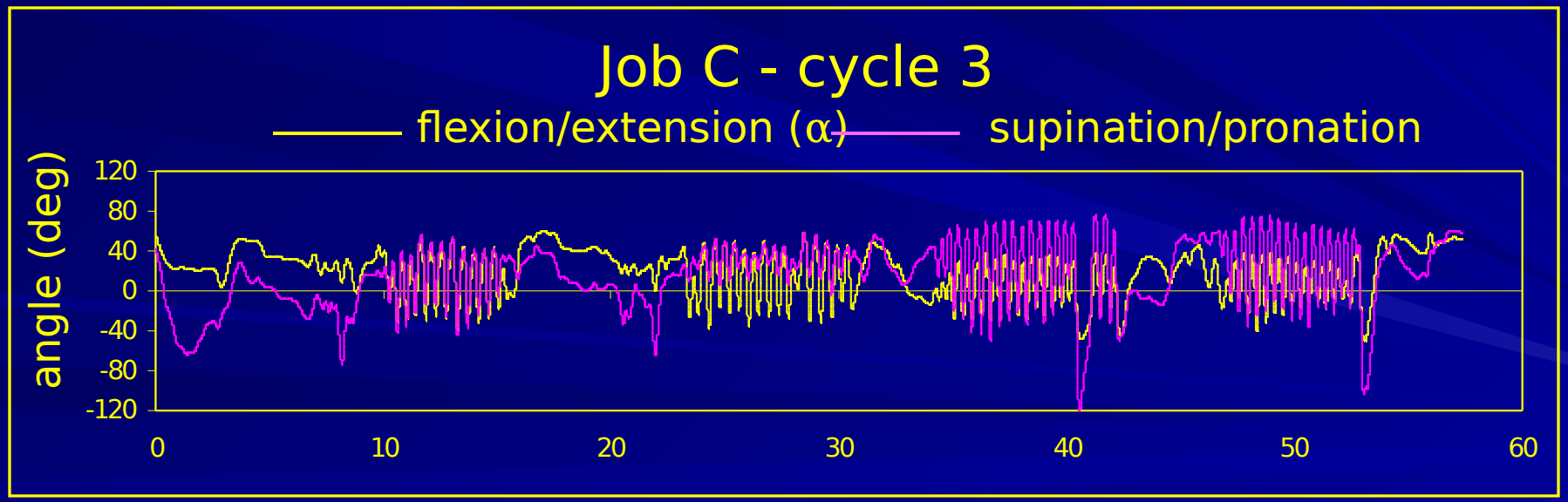
Job B
~ 8 s

Job C
~ 56
s

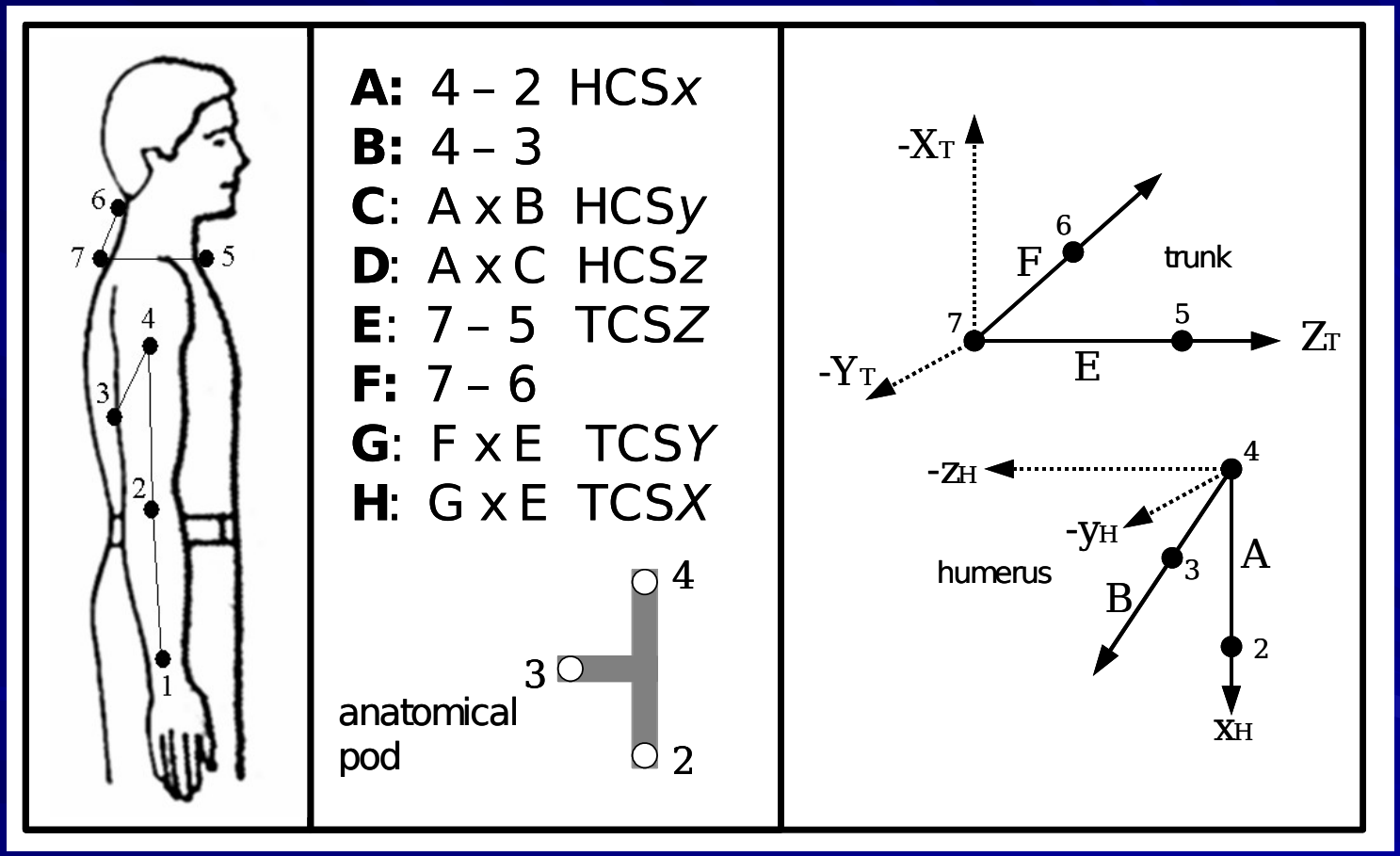
Job D
~ 46
s

electrogoniometer





optical motion capture



motion capture – shoulder kinematics

x – z’ – x” Euler angle sequence

φ: Rotation about x

θ: Rotation about z’

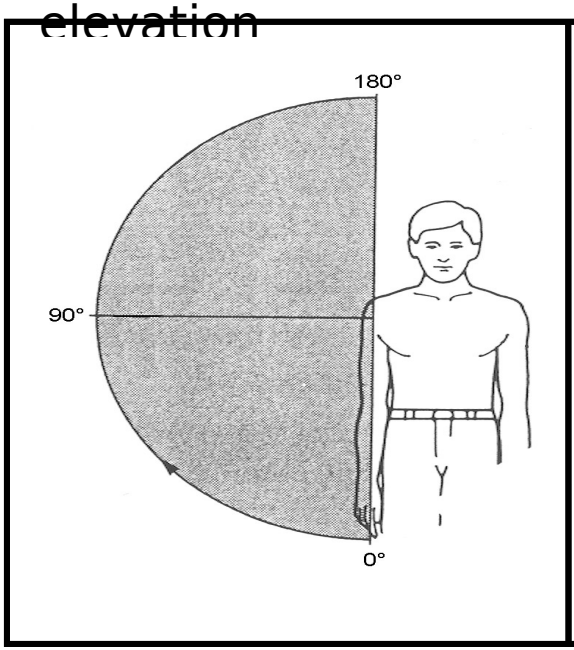
ψ: Rotation about x”

$\theta = \cos^{-1}(X \cdot x)$

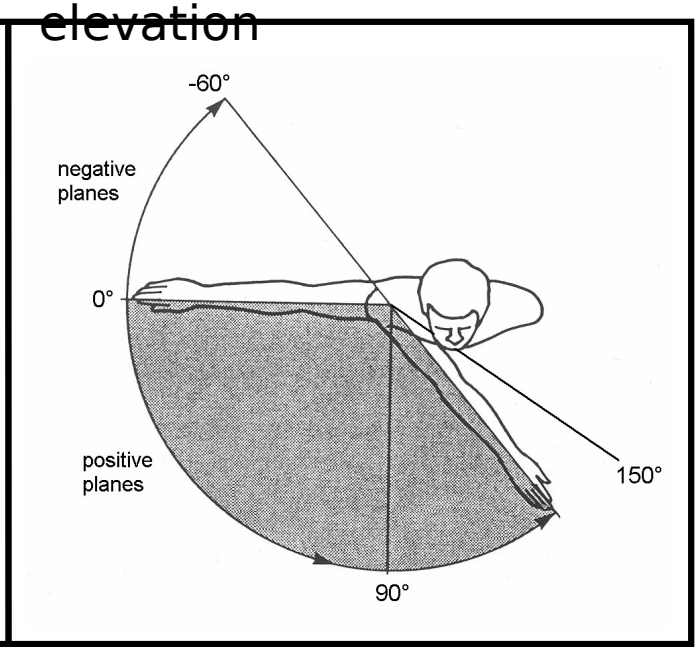
$\varphi = \cos^{-1}[(Y \cdot x)/\sin(\theta)]$

$\psi = \cos^{-1}[-(X \cdot y)/\sin(\theta)]$

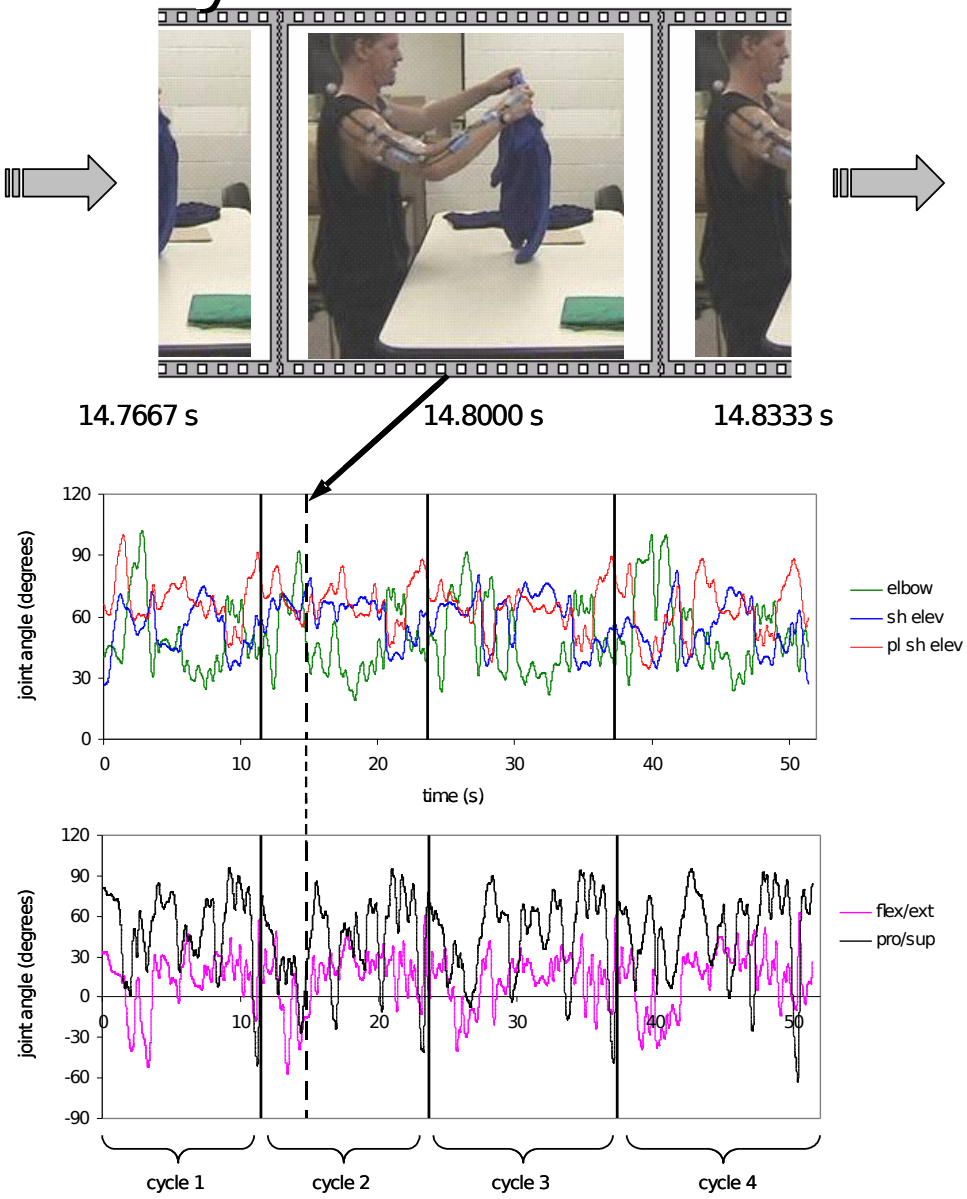
θ - shoulder elevation



φ - plane of shoulder elevation



video and instrumentation synchronization



participants and procedure

Participants

- 28 professional ergonomists
- 14 from academia,14 from industry/consulting
- 12 - Ph.D./M.D., 13 - M.S., 3 - B.S.
- Years experience in ergonomics (1 – 30 yrs.)

Procedure

- Assigned one method for posture analysis
- Estimated posture from video recording of jobs
- Analyses were unguided

posture scaling
method 1 – 3 categories

			1	2	3
mode	peak	wrist flex (deg)	>20°	20°-0°	
	peak	wrist ext (deg)		0°-20°	>20°
mode	peak	forearm sup (deg)	>40°	40°-0°	
	peak	forearm pro (deg)		0°-40°	>40°

	1	2	3
elbow flex (deg)	<40°	40°-80°	>80°
shoulder elev (deg)	0°-40°	40°-80°	>80°
plane of sh elev (deg)	<30°	30°-90°	>90°

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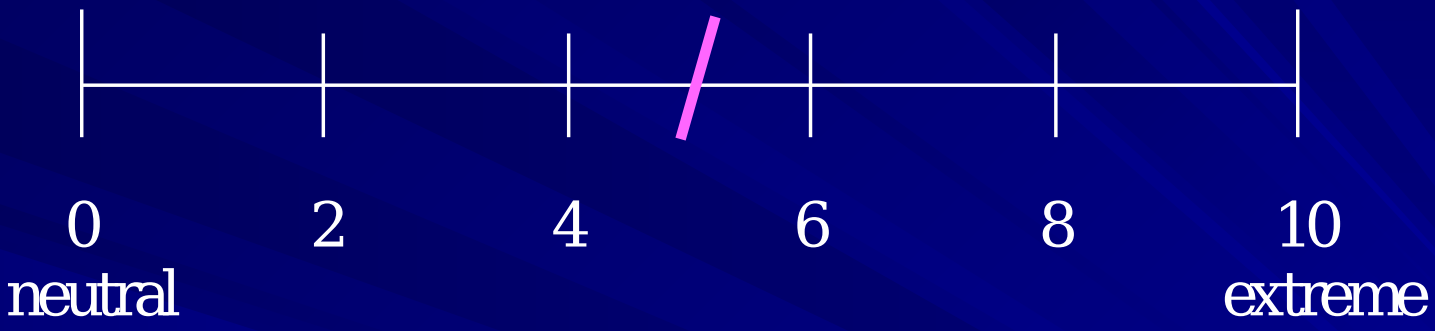
posture scaling
method 2 – 6 categories

	1	2	3	4	5	6
wrist flex	>45	45-20	20 -0			
wrist ext				0-20	20-45	>45
forearm sup	>60	60-30	30-0			
forearm pro				0-30	30-60	>60
elbow flex	<20	20-40	40-60	60-80	80-100	>100
shoulder elev	<20	20-40	40-60	60-80	80-100	>100
plane of sh elev	<0	0-30	30-60	60-90	90-120	>120

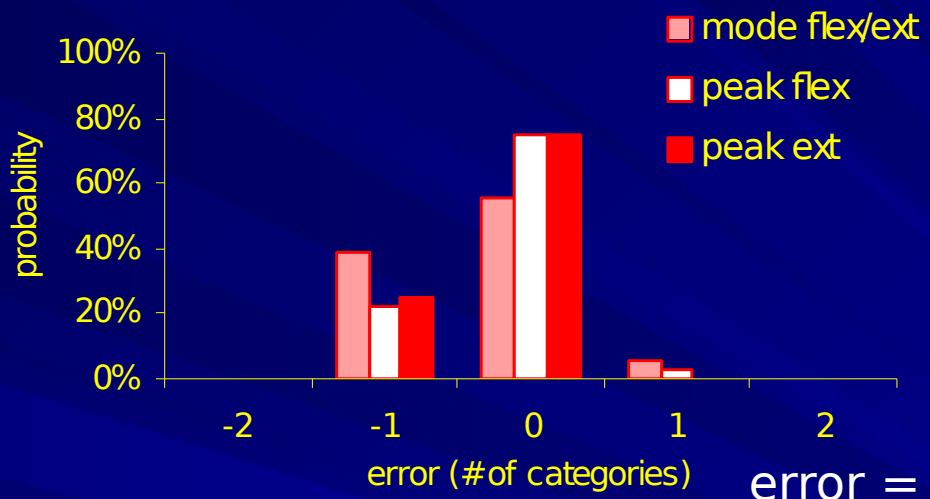
posture scaling
method 3 - visual analog scale (VAS)



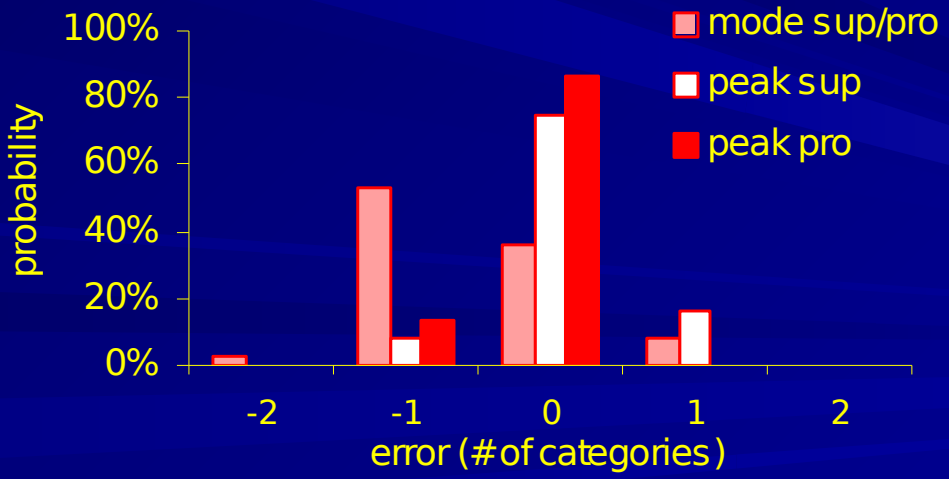
0°	wrist flexion	95°
0°	wrist extension	85°
0°	forearm supination	145°
0°	forearm pronation	135°
0°	elbow flexion	150°
0°	shoulder elevation	180°
0°	plane of shoulder elevation	150°

Results

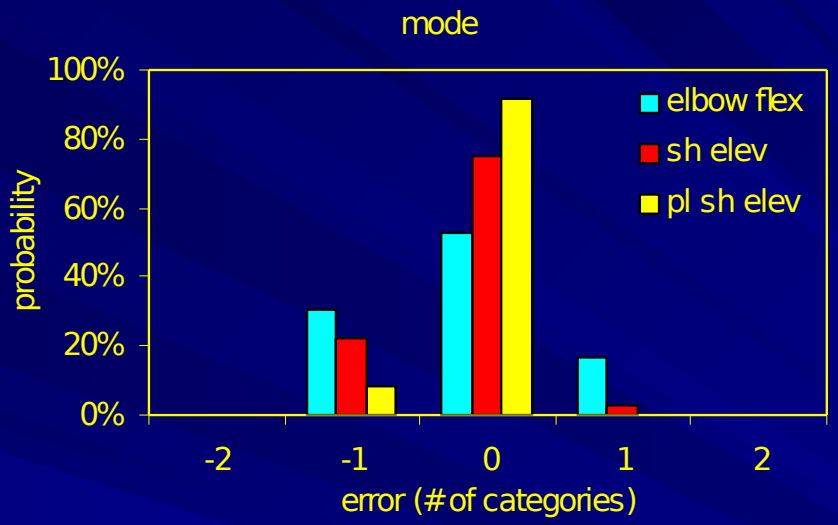
wrist/forearm – 3 categories (method 1)

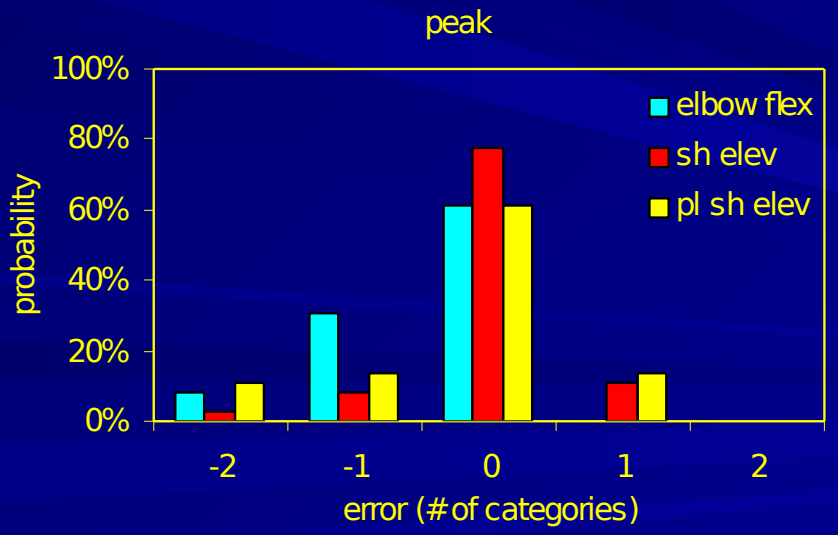


error = estimated - measured

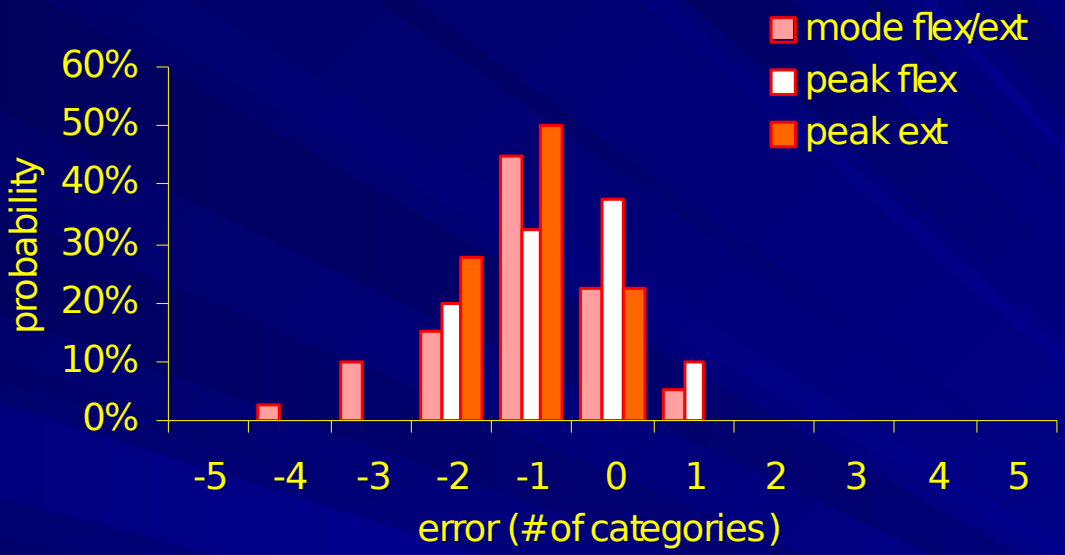


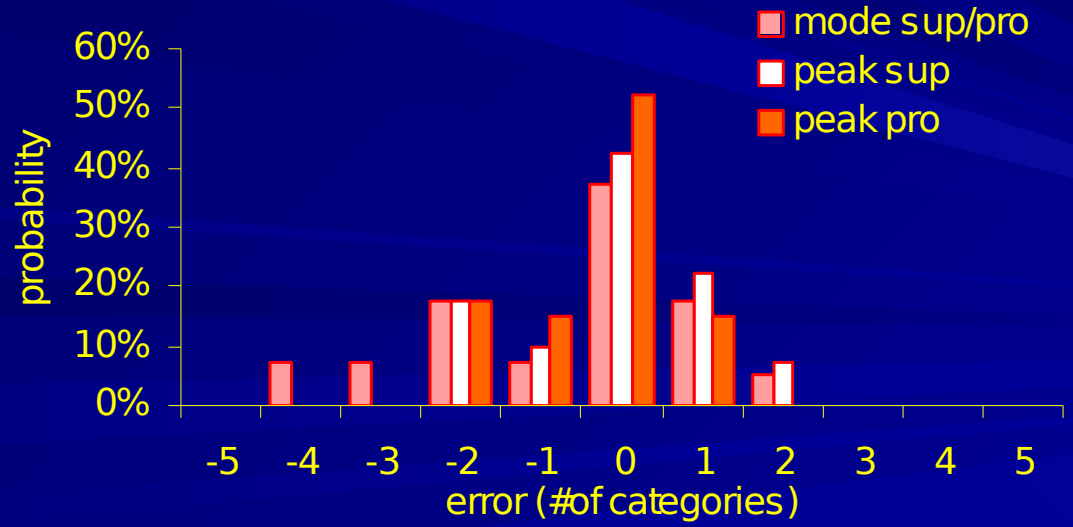
elbow/shoulder – 3 categories (method 1)



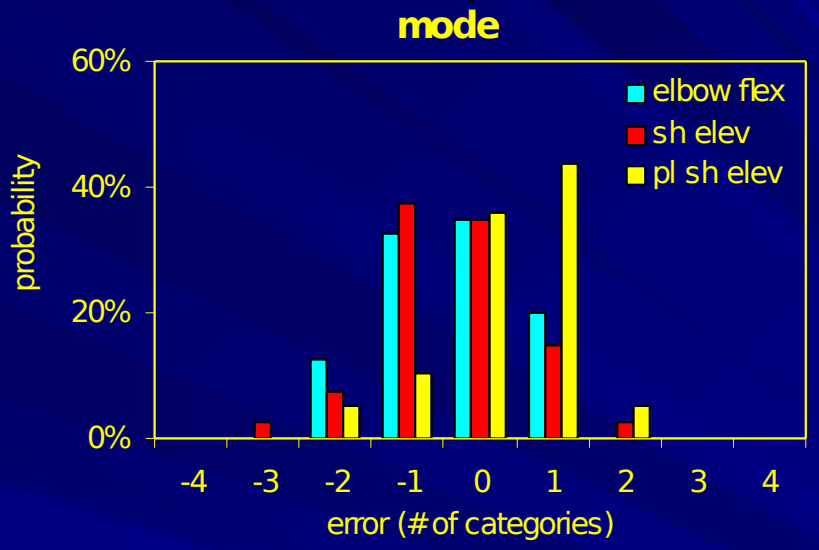


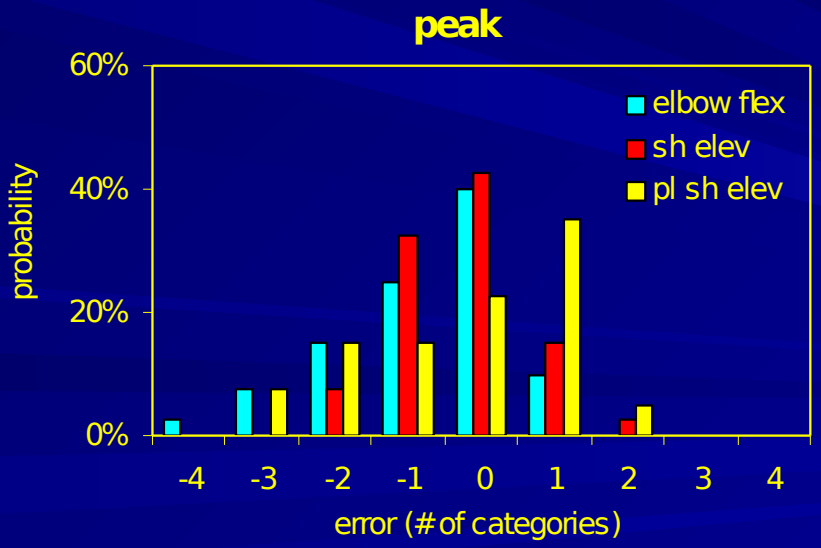
wrist/forearm – 6 categories (method 2)





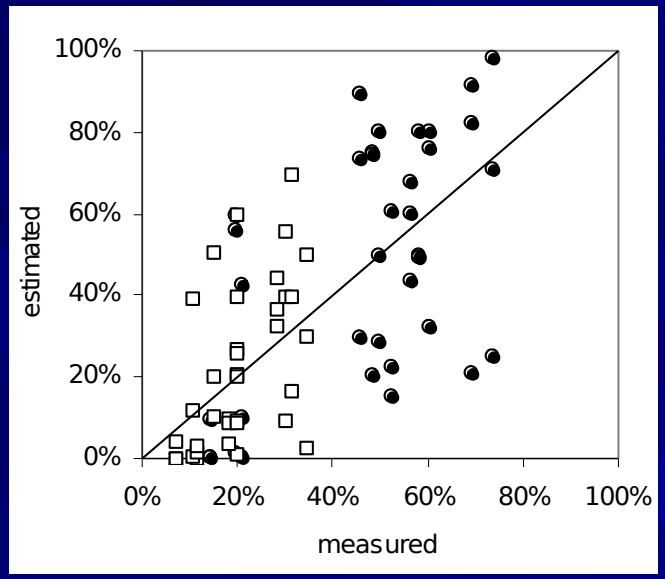
elbow/shoulder – 6 categories (method 2)





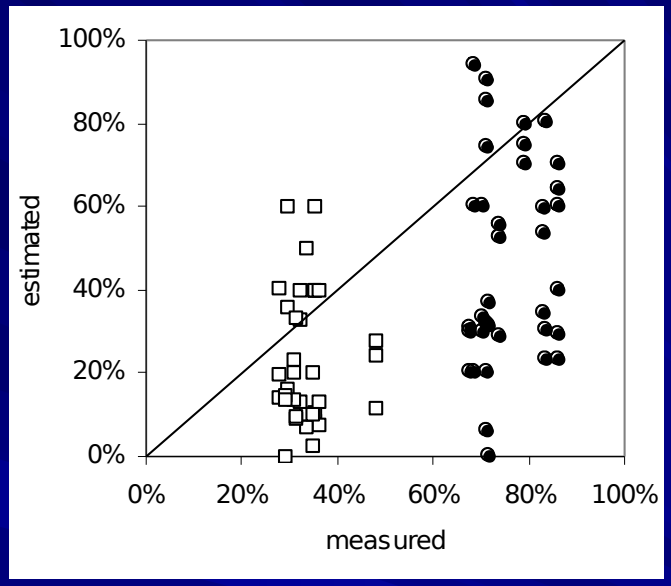
VAS – flexion/extension (method 3)

wrist flexion



$r^2 = 0.31$*
$r^2 = 0.28$*

wrist extension

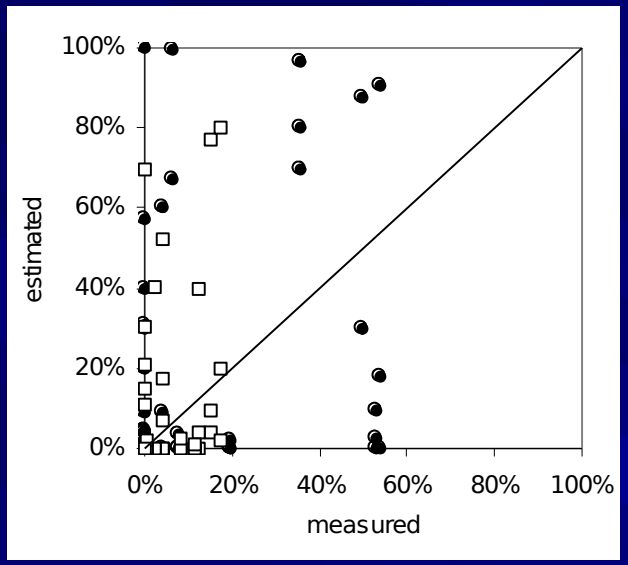


$r^2 = 0.02$
$r^2 = 0.00$

- peak
- average

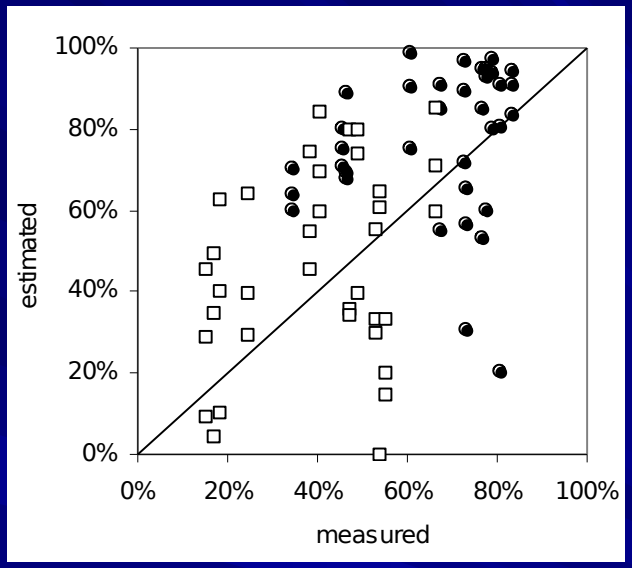
VAS – supination/pronation (method 3)

forearm supination



$r^2 = 0.02$
$r^2 = 0.03$

forearm pronation

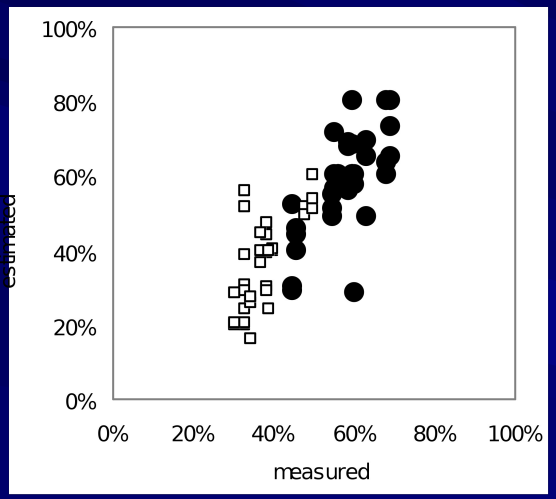


$r^2 = 0.02$
$r^2 = 0.09$

● peak
□ average

VAS – shoulder and elbow (method 3)

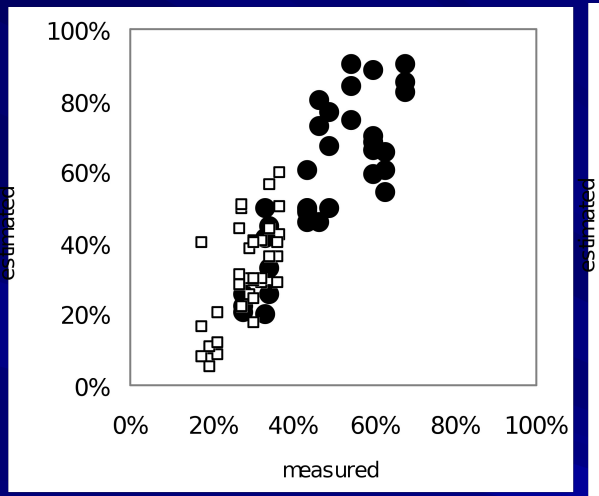
elbow flexion



$r^2 = 0.47^*$

$r^2 = 0.49^*$

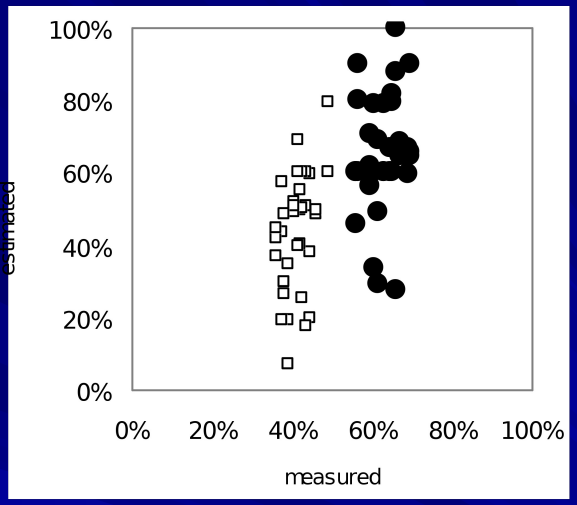
shoulder elevation



$r^2 = 0.66^*$

$r^2 = 0.46^*$

plane of shoulder elev +



$r^2 = 0.03$

$r^2 = 0.18^*$

● peak

□ average

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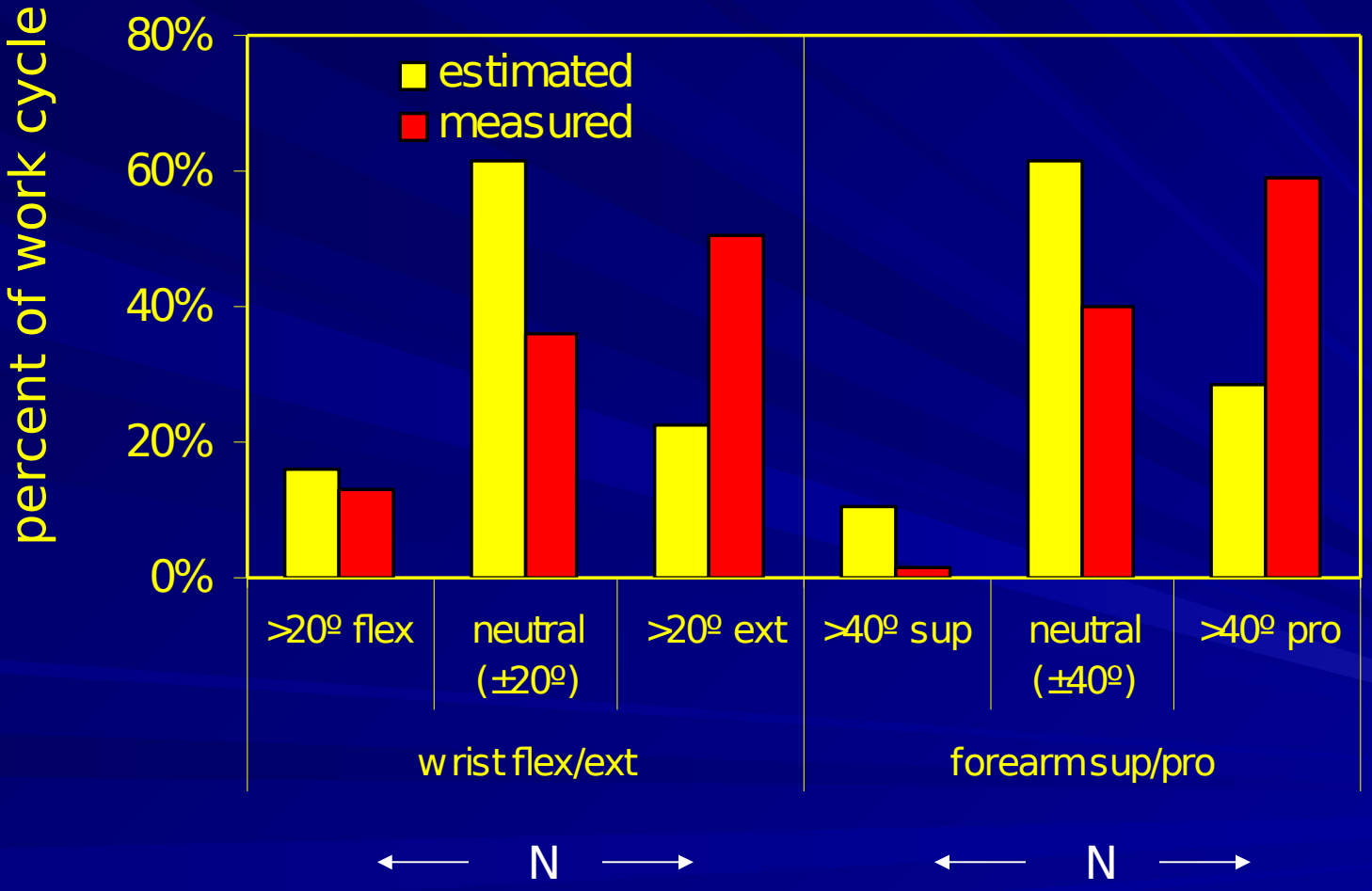
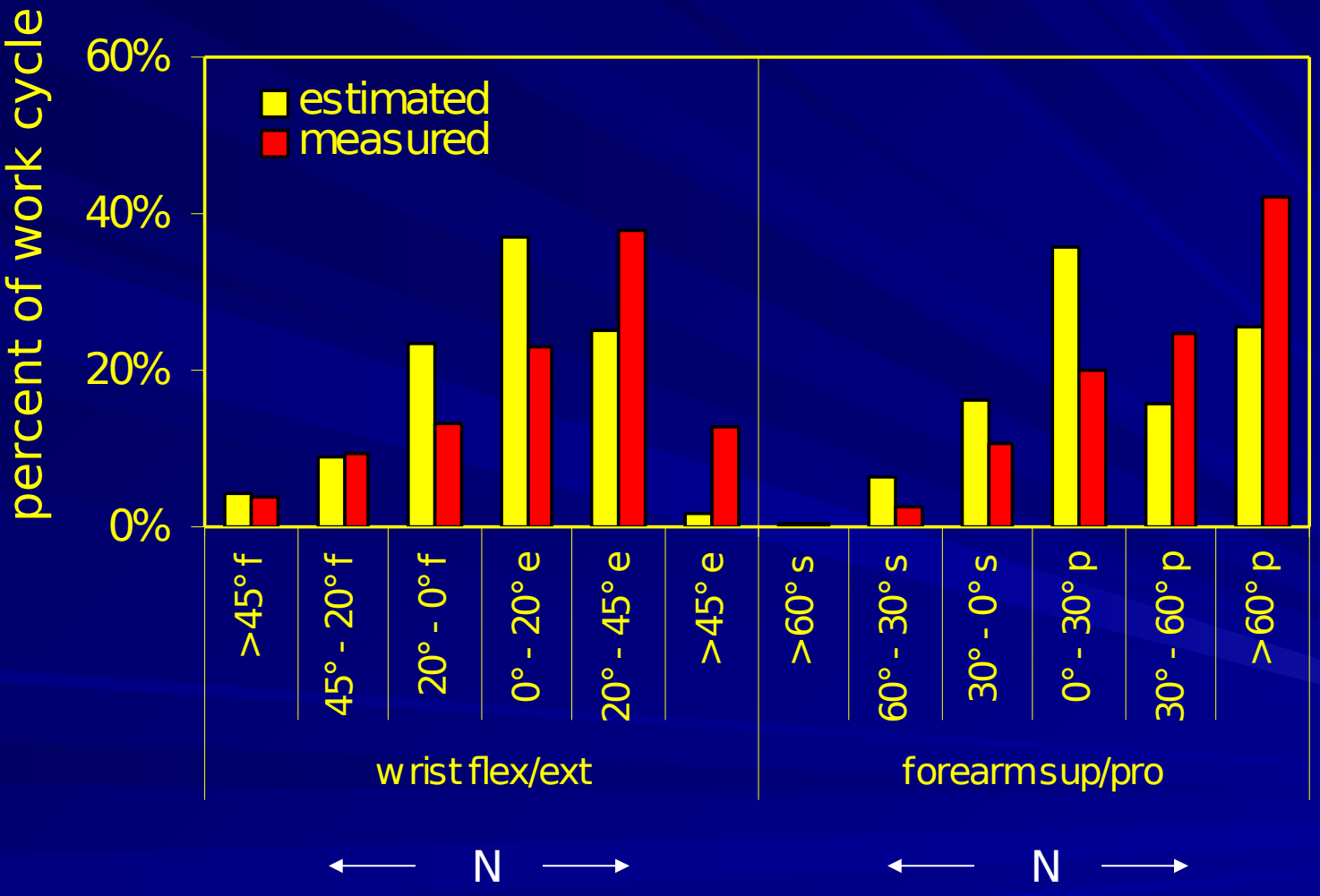
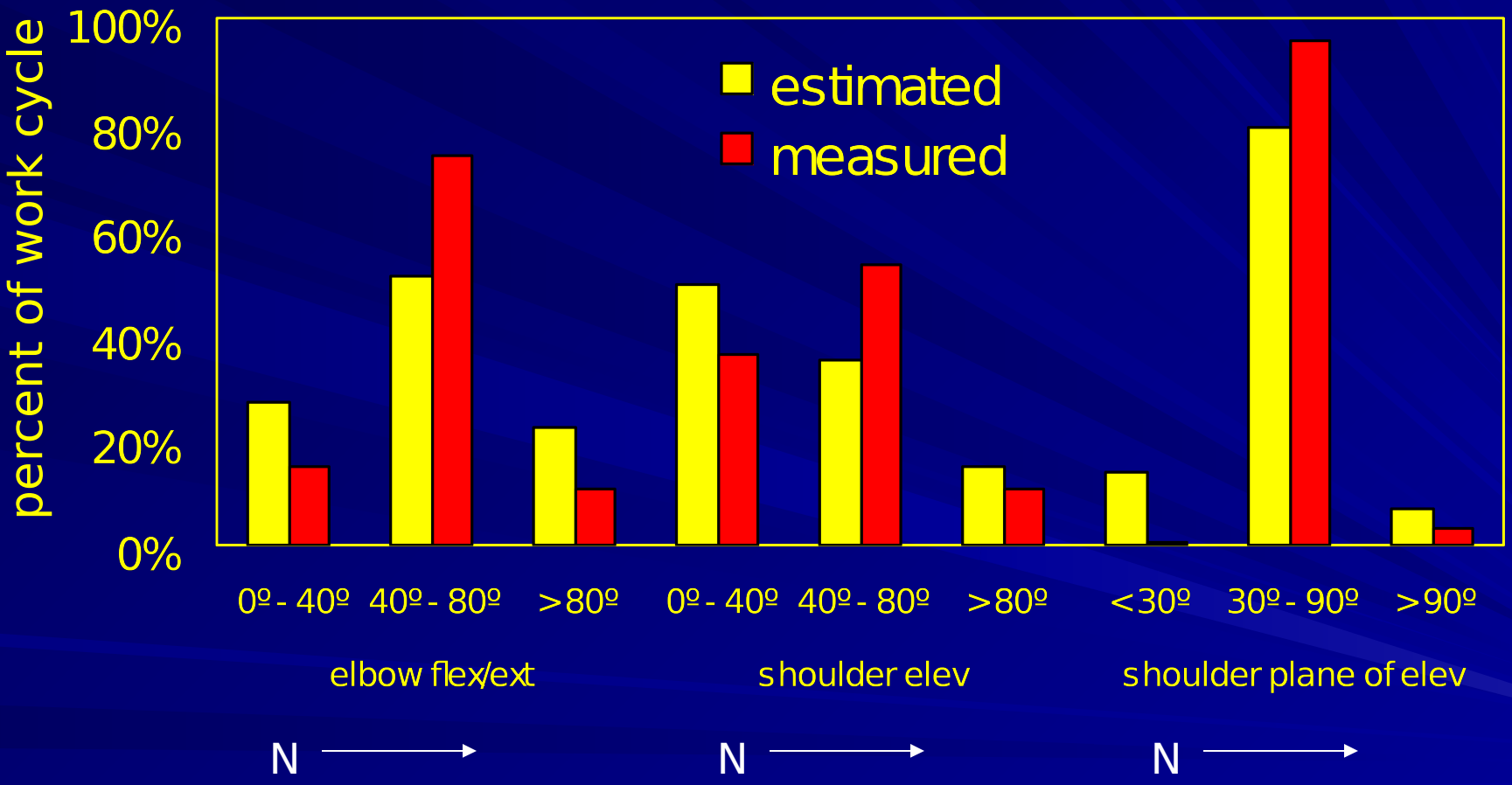
temporal distribution of posture
(wrist/forearm – 3 category)



temporal distribution of posture
(wrist/forearm – 6 category)

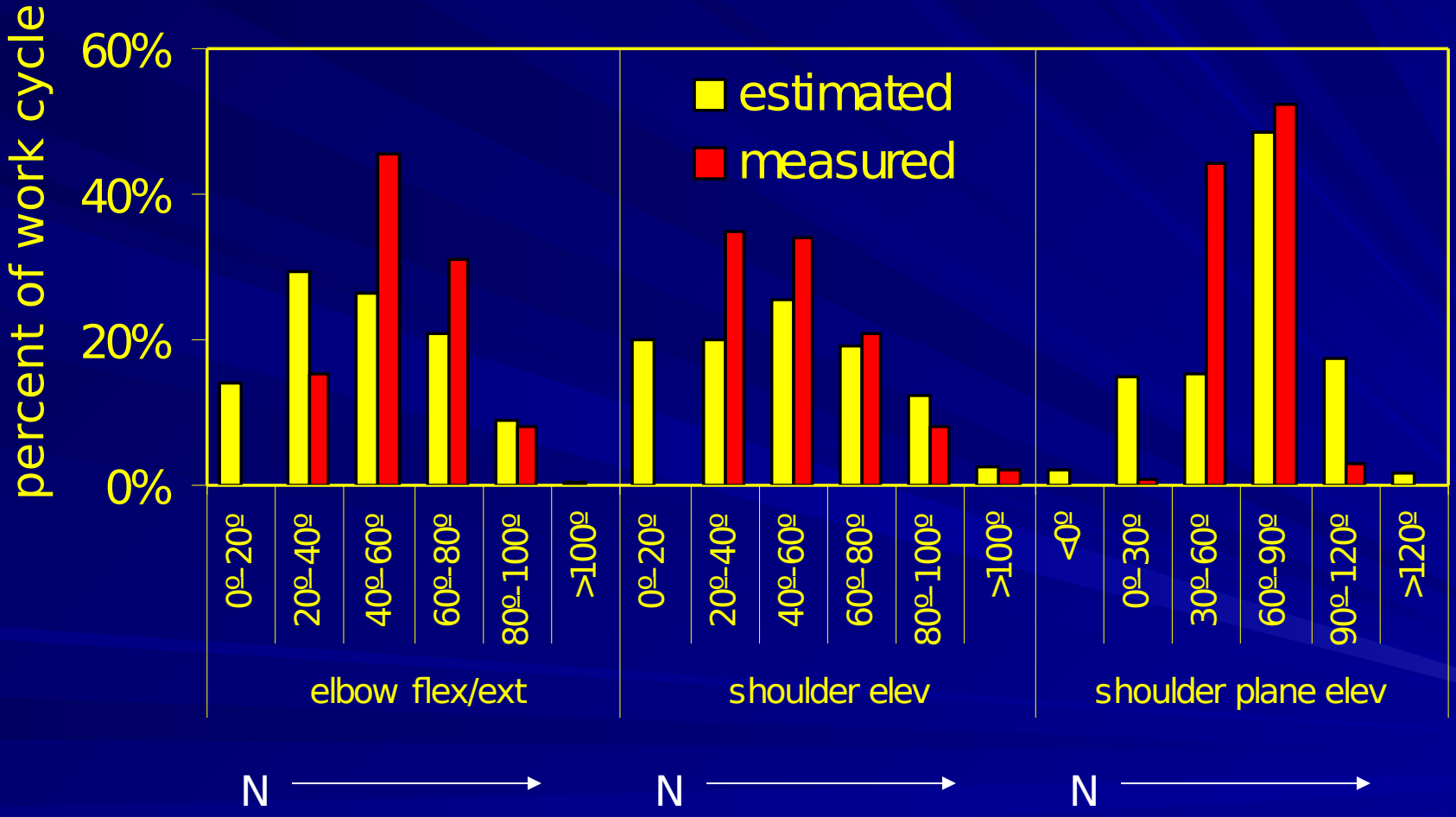


temporal distribution of posture
(elbow/shoulder – 3 category)



temporal distribution of posture

(elbow/shoulder – 6 category)



Discussion

- Performance does not necessarily reflect **best** case

  Limitations of the Study
  - Single video view
  - Simulated job tasks (laboratory study)
  - Analysts had no familiarity with jobs
  - Methods may not have been familiar to analysts
  - Little information regarding the strategy analysts used

- Intended to reflect performance in the **typical** case

summary of findings

- Posture classification accuracy related to the size of the joint/limb segments (Genaidy *et al*, 1993; Baluyut *et al*, 1995)
- Posture classification accuracy related to the number of scale categories
  - p(correct classification) = 73% for most frequent shoulder/elbow posture w/3 categories
  - p(correct classification) = 30% for most frequent wrist/forearm posture w/6 categories

validity considerations in job analysis

- Misclassification of working posture occurred in job analyses even when using a small number of posture categories
- Posture misclassifications with higher precision scale were more frequent, but their effect is less
- Duration severity of posture tended to be underestimated

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Acknowledgment

The contributions of Dan Habes, NIOSH, Ed Krieg, NIOSH, and Ahmed Khalil, University of Cincinnati are greatly appreciated.

Disclaimer

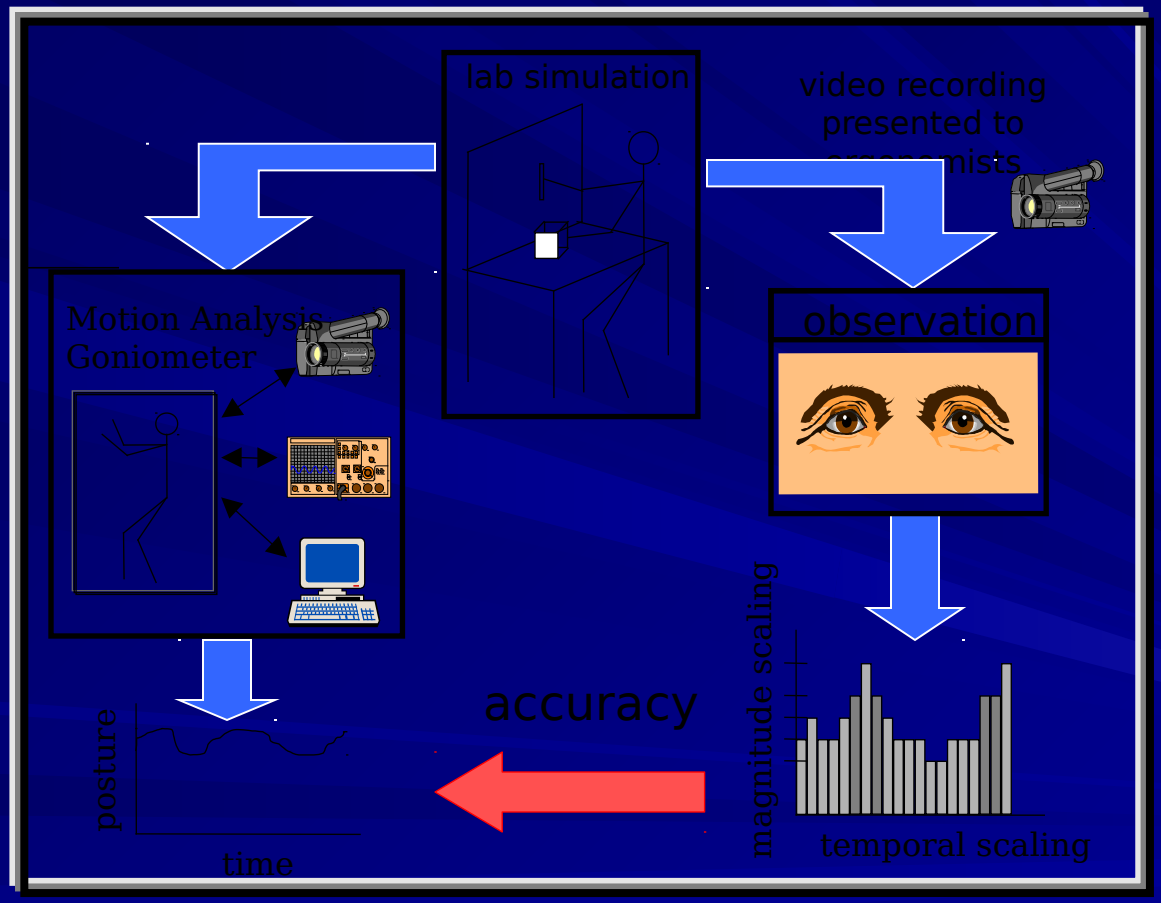
Mention of any company name or product, or inclusion of any reference, does not constitute endorsement by the National Institute for Occupational Safety and Health.

risk factors in physical work

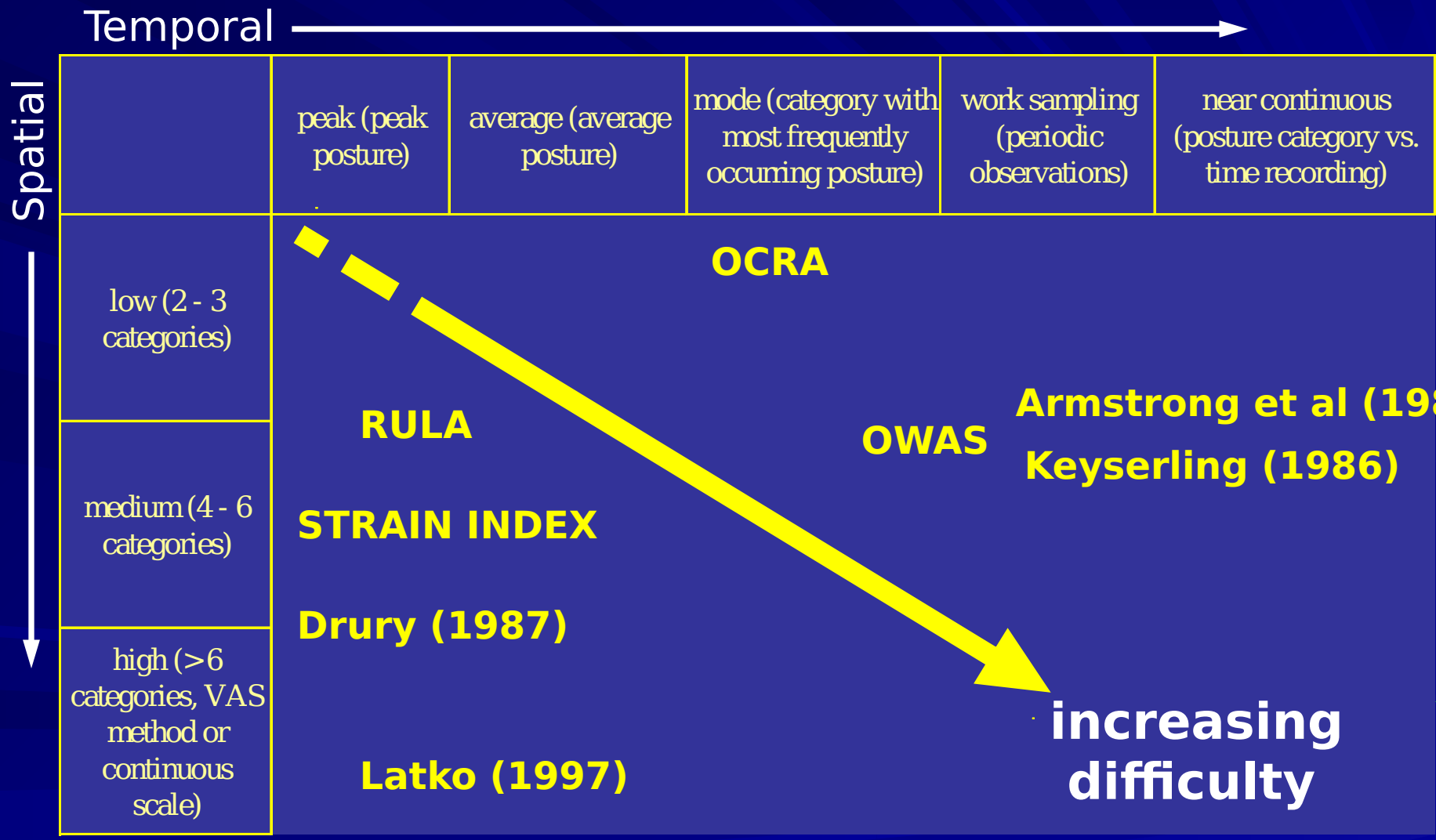
risk factors for work related musculoskeletal disorders (WMSDs)

- posture
- force
- repetition
- vibration

Ergonomic Exposure Assessment – Observational Accuracy

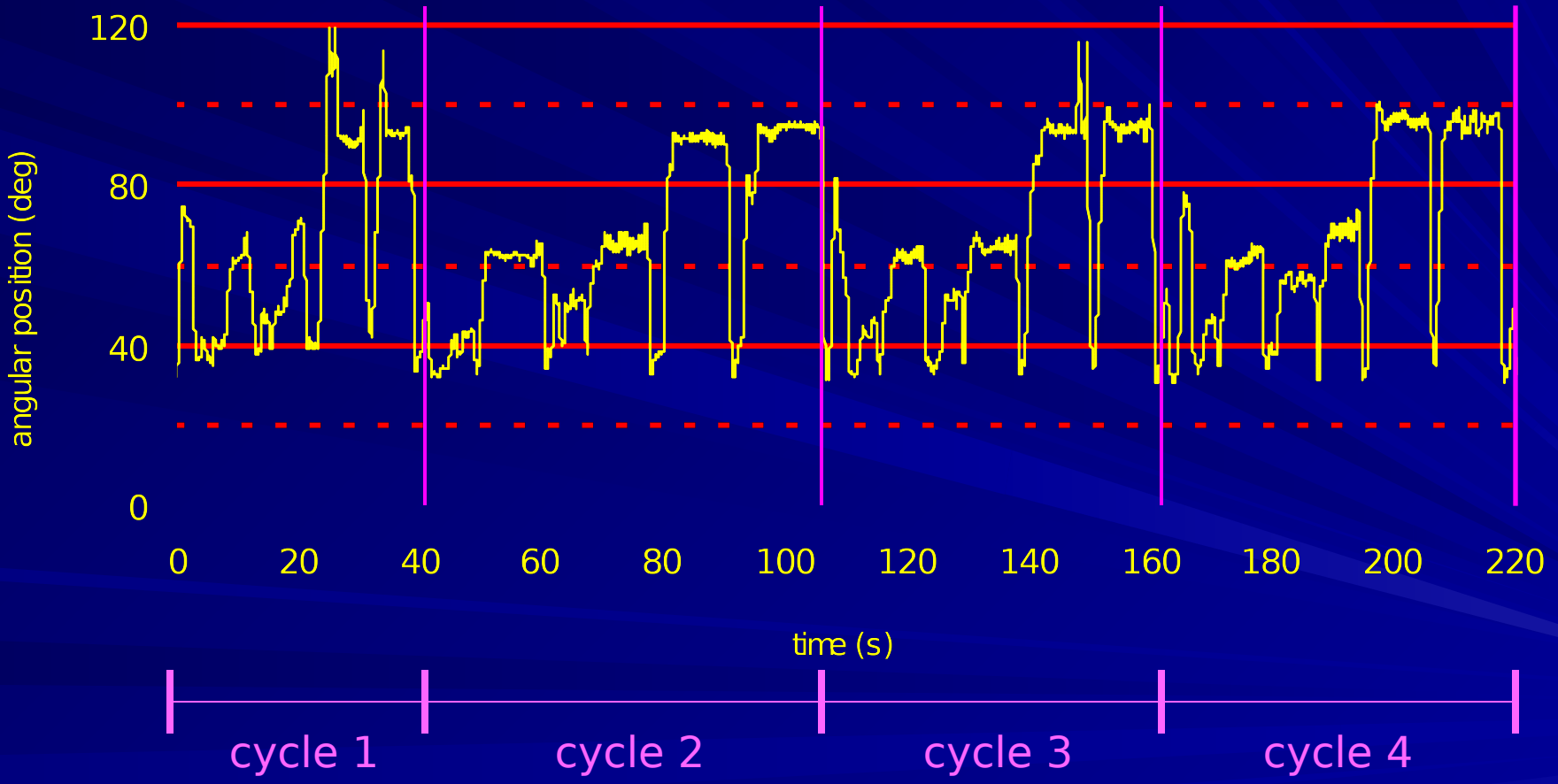


job analysis methods for the systematic observation of posture



work cycle analysis

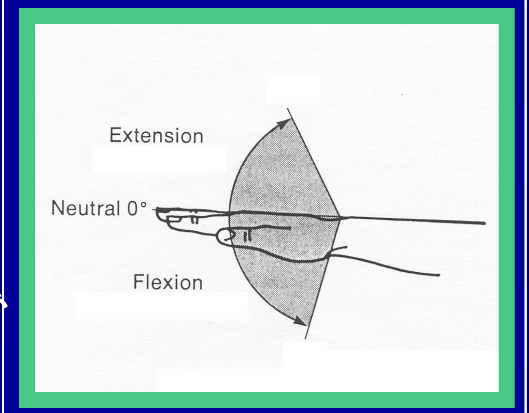
shoulder elevation – Job C

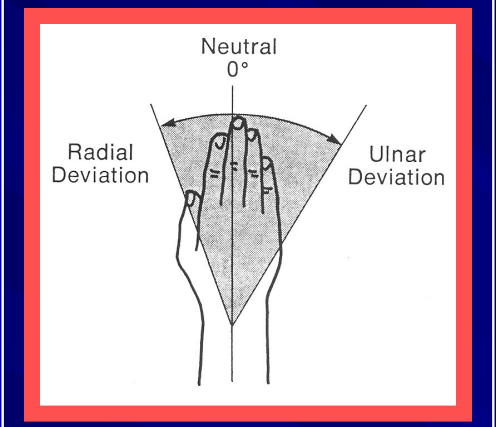


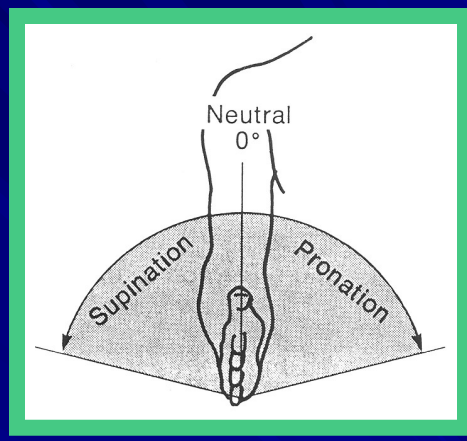
upper limb postures evaluated

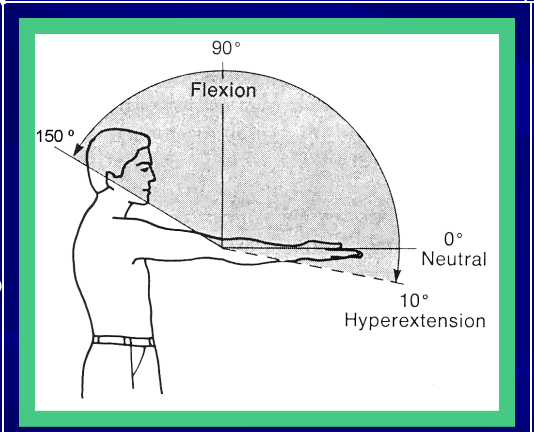
electrogoniometer

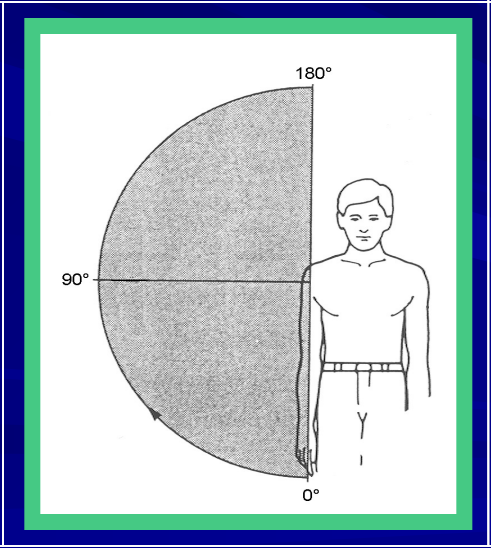
optical motion capture

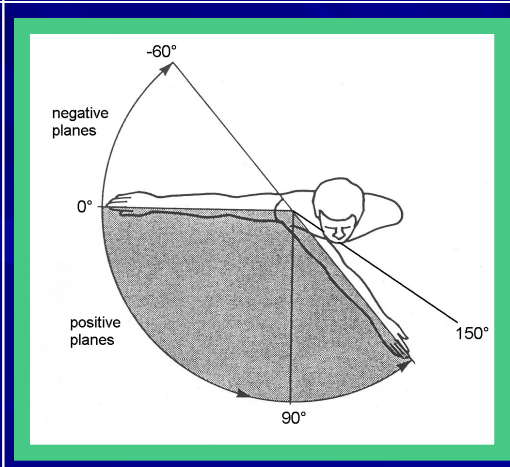












summary of other findings

- Time to completion of the analysis was not related to the resulting accuracy
- No relationship between years experience and accuracy of observational estimates
- No relationship between work cycle variability and accuracy of observational estimates

radial/ulnar deviation

- Inter-rater agreement statistics
- Intraclass correlation coefficient among raters (ergonomists) less than for flex/ext, sup/pro

	3-category	6-category
flex/ext	0.229	0.342
pro/sup	0.215	0.308
rad/uln	0.217	0.123

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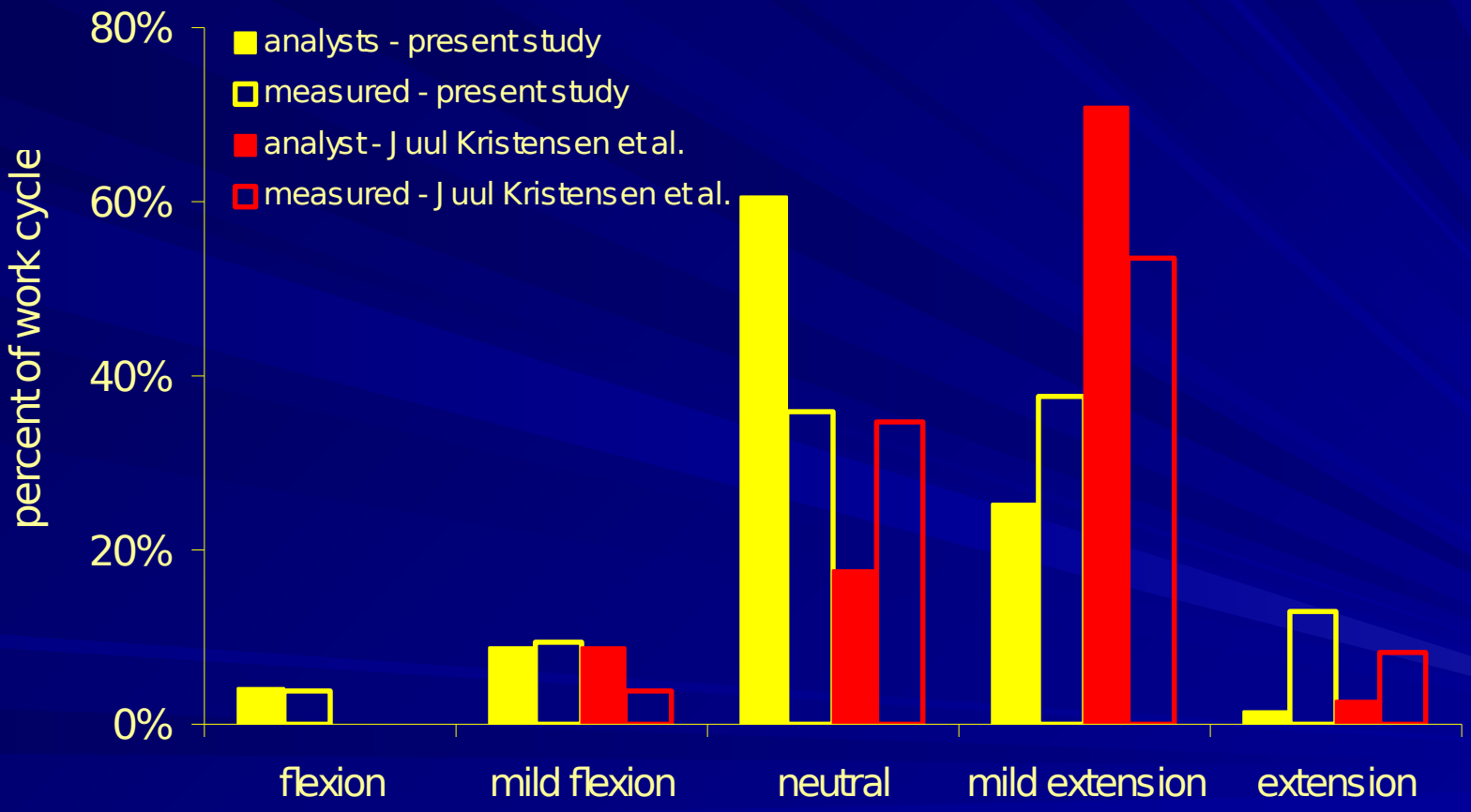
Juul-Kristensen et al. (1997)



Electrogoniometer Calibration

	R^2	maximum error
flex/ext	0.99	0.5° @ 45° flex
sup/pro	0.94	2.5° @ 45° pro
rad/uln	0.80	10° @ 30° uln

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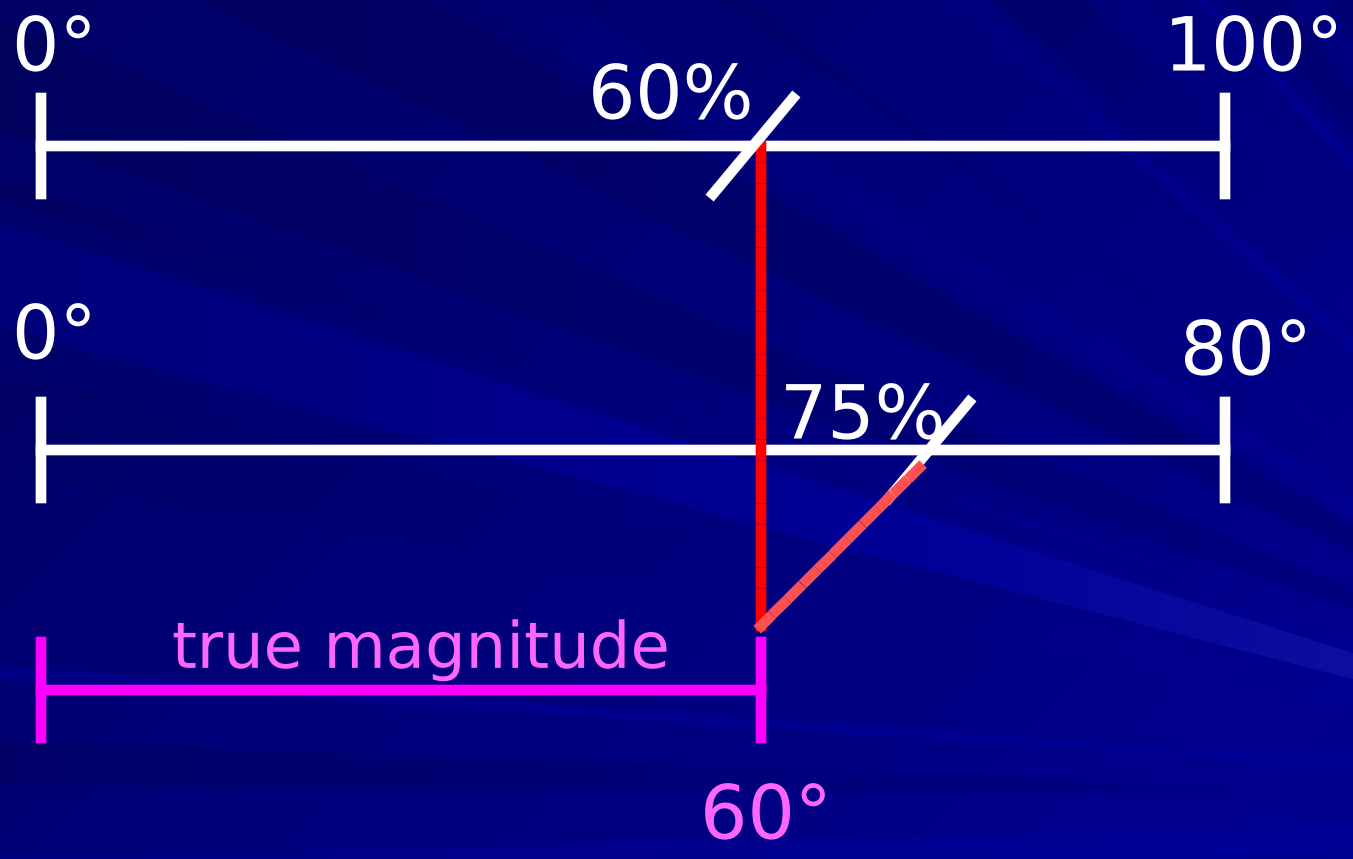
choice of ROM as VAS anchor



Observation vs. Chance

ergonomists' observation

measured \ estimated

	>60 sup	30 - 60 sup	0 - 30 sup	0 - 30 pro	30 - 60 pro	>60 pro	marginal
>60 sup	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30 - 60 sup	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0 - 30 sup	0.000	0.000	0.025	0.075	0.000	0.000	0.100
0 - 30 pro	0.000	0.000	0.025	0.150	0.075	0.050	0.300
30 - 60 pro	0.000	0.000	0.000	0.050	0.000	0.025	0.075
>60 pro	0.000	0.075	0.075	0.175	0.000	0.200	0.525
marginal	0.000	0.075	0.125	0.450	0.075	0.275	1.000

chance

measured

	>60 sup	30 - 60 sup	0 - 30 sup	0 - 30 pro	30 - 60 pro	>60 pro	marginal
>60 sup	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30 - 60 sup	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0 - 30 sup	0.017	0.017	0.017	0.017	0.017	0.017	0.100
0 - 30 pro	0.050	0.050	0.050	0.050	0.050	0.050	0.300
30 - 60 pro	0.013	0.013	0.013	0.013	0.013	0.013	0.075
>60 pro	0.088	0.088	0.088	0.088	0.088	0.088	0.525
marginal	0.167	0.167	0.167	0.167	0.167	0.167	1.000